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INTEGRATED MANAGEMENT OF CITARUM RIVER BASIN

A Case Study toward Sustainable Development and Community Participation

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Abstract

Water quantity is perceived as a problem to meet increasing demands of present human population for food, drinking, hygiene, and other domestic use and industry. However, quality aspect have also become a growing concern as a result of untreated release of domestic, urban and industrial discharges as well as non pint sources, e.g. agriculture. Citarum river basin is one of the biggest river basins in Indonesia. It covers 608 000 hectares, including 7 regencies and 2 cities (Bandung and Cimahi) in the province of West Java. Its huge source of freshwater have been contaminated from point and non-point sources of pollution, resulting in its very poor quality of very strategic and important source of freshwater in Indonesia for generating electricity, irrigating agricultural land, supplying fresh drinking water, and farming fish and also creating eco-tourisms. In order to protect this important freshwater resource, Agency for the Assessment and Application of Technology (BPP Teknologi) in collaboration with local government of West Java Province implementing environmentally sound technology to manage water quality of Citarum River Basin properly. The objectives of this project are (1) to protect freshwater resource from pollution, (2) to reduce pollution loads from point and non-point sources, (3) to introduce best available management for minimizing pollution, (4) to create sustainable community for best management practices to protect their water front village. Share experiences and exchange information, knowledge, and technology was done through ASEM Water Net to develop international partnership on Integrated River Basin Management

***Key words**: Integrated River Basin Management, Citarum, water quality, environmental pollution, freshwater resource,*

1. Introduction

Humanity has long been dependent on the earth's natural resources and, despite the apparent safeguards of technological advances, society are still fully dependent on ecosystems. Early scientific resource management viewed natural resources as limitless and was driven by an exploitative, co-modification approach based on efficient utilization. However, as is evident from the literature in the last three decades, human demand is pushing the capacity of these systems to provide life-support to society and threatening long-term socio-ecological sustainability.[1] In response, a number of new frameworks and strategies have evolved to address the concerns of sustainability with a greater focus on alleviation and equity. Development through a more holistic lens, many of these represent a fundamental departure from traditional assessment and planning tools. One such approach in the freshwater resource management is that of Integrated River Basin Management (IRBM). Integrated river basin management is intended to manage the various relevant factors in the basins in order to achieve multiple objectives for human resource use and protection of the aquatic environment. It is also an approach in which essentially takes a cross-sectoral and interdisciplinary approach to achieve institutional coordination and cooperation[2].

urgent and strategic to coordinate institutions that deal with freshwater resources and the marine environment in order to maintain the vital ecological linkages between rivers and the sea. Halting the destruction of the coastal areas is paramount if even a fraction of these genetically valuable resources are to be preserved. Therefore, the integrated coastal zone management (ICZM) strategies are needed to take account of population growth and distribution, urbanization trends, consumption patterns, generations of wastes and the use of available resources. Integrated coastal area management (ICAM or ICZM) is an appropriate tool for attaining this objective. Under the integrated coastal area management, coastal managers realize that freshwater input to the coastal areas has strong impacts on the coastal environment and welfare of the population living in those areas. The

Environmental Impact = Number of people x Resource use per person x Environmental impact per unit of resource used

Modification of river drainage basins by human activities has led to dramatic changes in the flow of water and nutrients they brings to the sea, for example nine hundred billion tones of water flow down China's greatest river, the Yangtze, every year.

In addition it powers the world's biggest hydro-electric scheme, slakes the thirst of 400 million people and serves as a rubbish dump for a growing number of super cities, factories, farms and ships. In nations worldwide, the interests that determine the amount of freshwater flow into the sea are seldom the ones that deal with the health of the marine environment. Therefore, it is imperative that development of effective mechanisms is very

physical and socio-economical relationship between the river basins and their corresponding coastal areas is also the basis for such an integrated approach to sustainable development. This new approach is known as Integrated Coastal Area and River Basin Management (ICARM)[3]. In line with the concept of sustainable development aiming at balancing the traditionally conflicting elements, namely, natural resources exploitation, social development and protection of the environment, inland water resources management is to achieve maximum benefits of human and ecosystems by balancing water resources exploitation, economic development of basins, and protection of aquatic environment, through institutional arrangements for cooperation and coordination among the water, environment, health, agriculture, industry and other relevant sectors at various level.

Similar experience mentioned above is happened to a Citarum's river system, one of the biggest and important and also strategic river basins in Indonesia. Citarum river basin system is located in the facinity of Bandung metropolitan city, in the province of West Java. Citarum river basin covers 680 thousand hectares from high mountain forest land areas, to irrigated lowland agricultural areas, including 7 regencies, Bandung, Sumedang, Cianjur, Purwakarta, Bogor, Bekasi and Kerawan; and two cities, cities of Bandung and Cimahi. Citarum River is the main longest river in Citarum river basin and one of the biggest rivers in Java Island, its length 300 km, where the water head is located in the mountain of Wayang, 2182 meters above sea level, on Kertasari village, Bandung Regency. Its river mouth is located in the cape of Kerawang, Bakasi Regency. Citarum river basin has 36 tributaries and approximately 873 km long.[4] In addition to its large coverage area and length, Citarum has three multipurpose-cascaded dams, including Saguling, Cirata, and Jatiluhur reservoirs. The first dam, Saguling covers 5 340 hectares mountain areas and its main function is to produce hydro electric power with full capacity around 700 MW. The second dam, Cirata covers 6 200 hectares and its function as hydro-electric power with full capacity up to 1000 MW and fish production in the floating cages with existing units up to 36 thousand. The third dams, Juanda previously Jatiluhur covers 8 300 hectares and its main function is to irrigate 240 thousand agricultural lowland areas, and as raw water for drinking water supply in Jakarta Municipal, and the water is also utilized for hydro-electric power with full capacity up to 150 MW. Therefore, according to Bukit dan Yusuf (2002)[5] Citarum river and its tributaries and multipurpose dams has very high potency and important function in terms of economics and environments, and it has high impacts on local people and culture strategically and socially.

Increasing population inhabited surrounding Citarum river basin is marked every year with growing rate up to 3 percent per year for the Regencies of Bandung and Cianjur. Meanwhile city of Bandung has a growth rate up to 3.6 percent per year. In the year 1994, population in the city of Bandung; Regency of Bandung, Cianjur and Sumedang is reached up to 6.67 million people. In the year 2010 is predicted by demographers reaches around 8.85 million[6]. Increasing population and growth rate led to big impacts on increasing wastewater and municipal solid wastes which is dumped into Citarum river basin. Means that pollution loads in the river system will be over burdened to bear in terms of river basin carrying capacity or assimilation rates, as a whole community does not care to put their waste into treatment facilities[6]. In addition, Salim (2002)[6] reported that pollution loads produced by human settlement (domestic wastewater) in the upper of Citarum basin was markedly to the pint of 200 078 ton/day in terms of Biological Oxygen Demand (BOD). Furthermore, he said that wastewater produced by industrial ecosystem was considered to be as high as domestic wastewater. Based on Sucahyo (1996)[7], in Citarum river basin there are 394 industries consist of 288 textile industries (73%), including 282 industries are located in upper basin in the cities of

Bandung, Majalaya, Banjaran and Cimahi. Textile industries are the biggest industry that utilized a lot of freshwater with consumption rate up to 43 940 m^3/day. All of those industries are located in surrounding city of Bandung required 60 593 m3 per day. Furthermore, Sucahyo (1996)[7] mentioned that in addition to domestic and industrial waste as main sources of pollution load in Citarum, unwisely agricultural activities were also source of non-point pollution to Citarum river basin, due to its high soil erosion, industrial fertilizers, pesticides and untreated domestic animal waste. According to Salim (2002)[6], that erosion rate in agriculture land was reach up to 1.32 – 5.2 mm per year. With this erosion rate, total sedimentation in Saguling reservoir was approximately close to 60 million m3. Based on Salim (2002)[6] that nitrogen and phosphor leaching from those actively cultivation in agricultural land, fertilizers and pesticides were also considered important to water pollution in Citarum river basin. The amount of nitrogen and phosphor leached to the Citarum river was up to 6 460 – 187 852 ton/year and 5 060 – 21 992 ton/year respectively. Consequently resulted in eutrophication in the river and triggered in the growth of phytoplankton and floating water plants such as ***Euchornia crassipes***, ***Silvinia natans***, ***Azolla***, etc. In addition to both fertilizers and pesticides residue including diazinon, methilation, and propoxur are toxic pollutants that can be accumulated and magnified in food chains and finally in human blood and body. Furthermore, Garno (2002)[8] informed that floating cage fisheries was also important source of water pollution in Citarum river basin. Pollution loads that resulted in from floating cages in Saguling, Cirata and Juanda in terms of organic pollutants (fish feed) was more than 29 869 tons per year, 145 334 tons per year and 14 492 tons per year respectively. Based on those data, Citarum river basin needs an integrated river basin management to protect huge important and strategic freshwater resource in West Java, Indonesia. Therefore, the Agency for the Assessment and Application of Technology (BPP Teknologi), through its Center for the Assessment and Application of Environmental Technology (P3TL) is trying to take care or handle this important river basin, and creating a cluster based environmental technology programs in order to protect and maintain, and wisely use of freshwater resource in Citarum river basin for the benefit of the river ecosystem and its people to sustain economic development in West Java, Indonesia. This cluster program has been promoted to the Asia-Europe Water Net (ASEM Water Net) to promote collaborative research among Asian and European countries to share their experience in protecting and maintaining their own important water resources. As member of this ASEM water net, Director for the Center of Environmental Technology (P3TL)-BPPT as a contact person has responsibility fto exchange information regarding water pollution and its technology solution to protect Citarum river basin as a whole in managing its tropical ecosystems and natural resources, including terrestrial and aquatic ecosystems.

2. Natural Systems in Citarum's River Basin

Based on geological and physio-graphic pattern and landform, Citarum river basin divided into 3 segments, including (1) upper Citarum river basin, consist of high mountainous areas up to Saguling dam, (2) middle Citarum river basin, including 3 cascades multipurpose dams, mainly land areas of 100-600 m above sea level, and (3) downstream Citarum river basin, including irrigated and productive agricultural land areas, coastal areas, and river mouth and estuarine areas. Upper river basin is mostly complex with environmental problems due to industrial areas, mostly populated and densely populated areas, most intensively agricultural land areas, which always produce highly and diversely organic and inorganic waste and wastewater as mentioned in previous sections. Upper Citarum river basin is divided into several sub basin, including (1) Sub basin Ciminyak, (2) Sub basin Ciwideuy, (3) Sub basin Cisangkuy, (4) Sub basin Cirasea, (5) Sub basin Citarik, (6) Sub basin Cikapundung, and Sub basin Cihaur. Based on division of sub basins, water quality monitoring was implemented based on community development. Biomonitoring are chosen to ease simply implemented environ-mentally sound technologies to support integrated and comprehensive river basin management in the Upper Citarum. The purpose of this decision is to promote and support actively community participation for planning, implementing, and evaluating of the decision support system to define objectives and goals of environmental protection and water quality monitoring in order to decide factors, parameters and indicators affecting the changes of environmental quality. Man has created and used technology based on his scientific achievements. Technical developments have improved the standard of living for many people in many countries. There are also high hopes that use of new techno-logies will lead to healthier lives, greater social freedoms and increased knowledge(9). The benefits, however, are unevenly distributed between and within countries. Other negative aspects are the depletion of natural resources, including deterio-ration of freshwater resource and negative environmental impacts.

Water quality has become increasingly important in water resource management for a number of reasons. Water use attracts more attention causing water quality to draw closer scrutiny. Water managers and the public have come to the realization that water quality affects other environmental interests, such as fish and wildlife, and can impact or impair water use. Increasing changes in water quality and other natural environmental quality resulted in environmental degradation and euthrophi-cation could successfully being approach-ed by Ecological Engineering (Eco-technology)(10). Eco-technology is defined as emerging field of science and technology capable of addressing a broad range of environmental issues. It will help people to influence the future of waste treatment, environmental restoration and remediation, food production, fuel generation, architecture and the design of human settlements. Meanwhile, ecology is the long-term intellectual foundation for the development of new technologies to support society. The workings and architecture of complex natural systems offer a blueprint for technological designs. These principles can be applied to design mesocosms for the purification of wastes using integrated living technologies based upon an ecosystems approach(11). Integrated mangrove-aquaculture systems currently practiced throughout Asia range from the traditional "***get wei***" in Hong Kong and "***tambak***" in Indonesia, to the state initiated silvo-fisheries in Indonesia, mixed mangrove–shrimp farm systems in

Vietnam, aqua-silviculture in the Philippines, and mangrove pens in Malaysia.[13] Eco-technology is also approached perspective to describe interdependently between system management of environmental technology and system of bio-geophysics. This approach is focused on the roles of environmental technology within bio-geophysical system in order to minimize wastes and to maximize recycling of materials and energy. With this interaction between system management of environmental technology and system of bio-geophysics led to a creative model on impacts of environmental technology to natural resource degradation as is mentioned as follows:[12,14,15,16]

$$F = SR - (Q3 + Q4)$$
$$SR = P - I - (T + E)$$
$$I = Q1 + Q2$$

Therefore:

$$F = P - (Q1 + Q2) - (T + E) - (Q3 + Q4)$$

Where:

F	:	flash flood due to the amount of water is over reach its channel capacity,
SR	:	surface run-off, the amount of water flow on the ground or in the channel,
I	:	Infiltration, the amount of water infiltrated into the groundwater basin,
P	:	Precipitation, the amount of water that can reach the ground from rain,
T	:	Transpiration, the amount of water evaporated to the atmosphere from plants,
E	:	Evaporation, the amount of water evaporated from the ground,
Q1	:	Natural recharge, the amount of water recharged into the ground basin naturally.
Q2	:	Artificial recharge, the amount of water recharged into the ground basin with the help of human activities.
Q3	:	The amount of water which is existed or stayed in the channel.

Environmental degradation can be described as a product of population, resource use per person (affluence) and environmental damage per unit of resource used (technology)[12]. In Earth summit at Rio de Janeiro, the US delegation wanted to remove all references to consumption (resource use per person from Agenda 21 document and Bush administration pointed out that "the American lifestyle is not negoti-able". Meanwhile, low-income nations retaliated by removing references to the urgent need to slow population growth. They wanted to shift responsibility for environmental problems onto industria-lized nations. The political will is needed for taking action on the concept of sustainable development to accom-modate world's economic growth, means that the achievement of sustainable development will depend on our ability to reduce the environmental impact of resource use through technological change.[12]

According to Branson et al. (1981)[17] that a model provides tools to transfer science and technology from measured area into unmeasured area where management decisions are needed to be addressed. A model of environmental management provides quantitative expression from an area being observed or analyzed or predicted and it will give double benefits to the manager based on factors or parameters or indicators determined changes in environmental quality and quantity of natural resources. Fundamental concept of protecting flash flood is to minimize surface run-off and increase water to infiltrate into the groundwater basin, as stated in the following formulations:

In actual, Q2 and Q4 are of human efforts through environmental technology to increase natural capacity to promote water distribution evenly. Those efforts were needed in order to protect flooding due to degradation of natural resources because of their capacity to deliver water is reduced. Therefore, conservation of soil and water resources considered human efforts to minimize drastically changes in natural capacity to assimilate or attenuate in controlling flash flood, for example flooding areas should be protected for water parking facilities, because due to its ecosystem function, however those function have been taken an converted into agricultural land, industrial, and human settlements. This example is one of several problems facing human activity using technologies to change nature and reducing its capacity to assimilate, control, and recovered from environmental degradation. If human is aware that technology has two sided eyes, one is able to kill and the other is able to help people to restrain problems in order to obtain their way of life to defend the only earth that can be used sustainable by generation to generation. Human should be able to know that both structure and function of natural environments are very important components to increase its attenuation ability to suppress pollution. Regression model created by Pindyck and Rubinfeld (1991)[18] stated that the following formulation could be used as a fundamental concept to predict factors affecting environmental degradation. This formulation can be led to find technological solution to protect and control environmental degradation that could be emerged in Citarum river basin. The basic formulation is stated as follows:

$$Y(x) = f(X1, X2, X3, X4, X5, \dots\dots\dots\dots, Xn)$$

where,

Y(x)=Total magnitude of environmental impacts in Citarum river basin
X1=factors affecting industrial ecosystems to produce wastages,

X2 =factors affecting human settlement as a created ecosystem,

X3 =factors affecting agricultural ecosystems as a non point source,

X4 =factors affecting tropical rain forest ecosystem degradation, and

Xn =other factors affecting Life Support Ecosystems.

If natural processes generated unuseable waste, higher forms of life would no longer be possible. Contribution to the ongoing changes from current technology with its excessive waste generation to future no-waste technology is effectively encouraged. Ecologically sound wastewater management will play a key role in the quest for the efficient use and reuse of water, long-term soil fertility and protection of the natural resources, including water resources. Zero emission approached technology aims to reuse and recycle at 100% of all materials produced by industries. The same principles can be applied to municipal waste management, ending the concept of "end pipe technology". Sanitation systems can be designed to be more efficient; old and new technology can be applied in source control systems. So sanitation systems are being a production unit that can provide high quality reuse water, safe fertilizers and soil-improving material (including processed bio-waste where appropriate). This could be called "resource management" in source control system, because there will no longer be any wastewater. Today such approaches exist and can be applied and currently being planned, built and operated pilot systems using eco-technological skills which are more economic and ecologically sound technology and sustaining life support systems for future generations.

3. Objectives and Goals

Management objectives:

(1) To develop integrated and participative management on Citarum river basin effectively for controlling water pollution and restoring environmental degradation, especially riverine ecosystems in order to achieve water quality standard nearly close to naturally pristine and healthy ecosystem allowing to ensure better ecosystem structure and function of Citarum river basin (be the best achievable ecosystem structure and function for life support system).

(2) To support relationships and understanding among stakeholders especially community participation on the development of ecosystem potency and preferably structure of Citarum river basin that could be utilized for generations (Community participation and sustainable development).

Management goals:

(1) An integrated management approach will optimize policy interventions in space and time to reduce potential conflicts; bridge the potential gaps and streamlines potential overlaps between policies. This approach can be achieved through recognition of key linkage between river basin and coastal area systems, including both natural processes and human activities.

(2) An integrated approach will optimize community preparation for social engineering to actively involve in community participation project in planning, implementing and evaluating applied science and technology for managing Citarum's life support systems.

(3) An integrated approach can be replicated into different geographical scale among various processes operating in river basins in supporting decision-making process in the future, through environmental awareness, environmental campaign in mass media, printed or electronics and films, making books and several important technical guidelines, concise, simple and easy to understand in maintaining proper function of river basin ecosystems.

(4) An integrated approach involves several stakeholders to form institutional framework and planning for sustainable management of river basins.

(5) An integrated approach will be set an independently river basin authority to keep in touch within one

river, one planning and one direction of management goals.

4. Conceptual Implementation of Environmental Technology in Citarum River Basin

Environmental technology is defined as a technology or any manufacturing action that works within the natural cycle of the ecosphere to ensure that the process produces materials that are biodegradable, and uses the whole range of biodiversity in a holistic and non-invasive way with the aid of efficient engineering, and fit into socio-cultural patterns and serve humankind. Human societies derive many essential goods from natural ecosystems, including seafood, game animals, fodder, fuel-wood, timber, and pharmaceutical products. These goods represent important and familiar parts of the economy. What has been less appreciated until recently is that natural ecosystems also perform fundamental life-support services without which human civilizations would cease to thrive. These include the purification of air and water, detoxification and decomposition of wastes, regulation of climate, regeneration of soil fertility, and the production and maintenance of biodiversity, from which key ingredients of our agricultural, pharmaceutical, and industrial enterprises are derived. This array of services is generated by a complex interplay of natural cycles powered by solar energy and operating across a wide range of space and time scales. For example, the process of waste disposal involves the life cycles of bacteria as well as the planet-wide cycles of major chemical elements such as carbon and nitrogen. However, threats to these systems are increasing suppressed our ecological structures and functions led to changes in their supply or deterioration of life support systems, for example deforestation has belatedly revealed the critical role of rain forest to serve in regulating the water cycle, in particular in mitigating floods, droughts, the erosive forces of wind and rain, and silting of dams and irrigation canals. Although freshwater is a renewable resource, it can become so contaminated by human activities that it is no longer useful for many purposes and can be harmful to living organisms using the water. The level of purity required for water depends on its use. Water too polluted to drink may be satisfactory for washing steel, producing electricity at a hydroelectric power plant, or cooling the steam and hot water produced by a nuclear or coal fired power plant. Water too polluted for swimming may not be too polluted for boating or fishing or culturing fish or irrigating rice fields. Water pollution is a local, regional, and global environmental problem and is connected with air pollution and how we use the land. Some of the fertilizers and pesticides applied in agricultural land for crops run-off into nearby surface waters or leach into aquifers. Poor land use accelerates the erosion of soil that pollutes surface waters with sediment. Some of the sludge and other wastes we produce on land, such industrial activities, agricultural practices, cities and villages activities are dumped into the rivers, groundwater, and finally gone to the oceans. In order to control and regulate water resources, it is useful to distinguish between point sources and non-point sources of water pollution from human activities. Point sources discharge pollutants at specific locations through pipes, ditches, or sewer into bodies of surface water. Because point sources area at specific places, they fairly easy to identify, monitor and regulate. Meanwhile non-point sources are big land areas that discharge pollutants into surface and underground water over a large area (see Figure-1). According to Miller (1990)[15], in the US, as a comparison, non-point pollution from agriculture is responsible for an estimated 64% of the total mass of pollutants entering rivers and 57% of those entering lakes.

Integrated River Basin Management (IRBM) is intended to manage the various relevant factors in the basins in order to achieve multiple objectives for human resource use and protection of the aquatic environment. IRBM offers a strategy and framework for organizing thinking and action within a catchment context to ensure and recognize link ages not only of land-water and upstream-downstream systems, but also of socio-ecological systems, including institutional roles, responsibilities and actions that can restore and maintain, and enhance the ecosystem's capacity within river basin. However, UNEP's approach has expanded the scope of such integrated river basin management to include also affected coastal areas to form the Integrated Coastal Areas and River Basin Management (ICARM)[3]. ICARM provides the key to the integrated development of natural, economic and cultural environments within river basins and coastal areas. The following figure is to draw a concept in managing and protecting in the upstream river ecosystems through in-plant and in stream monitoring units to provide rapid biological information in a river management system. Application of environmental technology could help managers to alleviate pollution loads that produced by mixed industrial and agricultural ecosystems in Citarum river basin.

5. Application of Environmental Technology for Citarum River Basin

Based on the roles of environmental technology within bio-geophysical system in order to minimize wastes and to

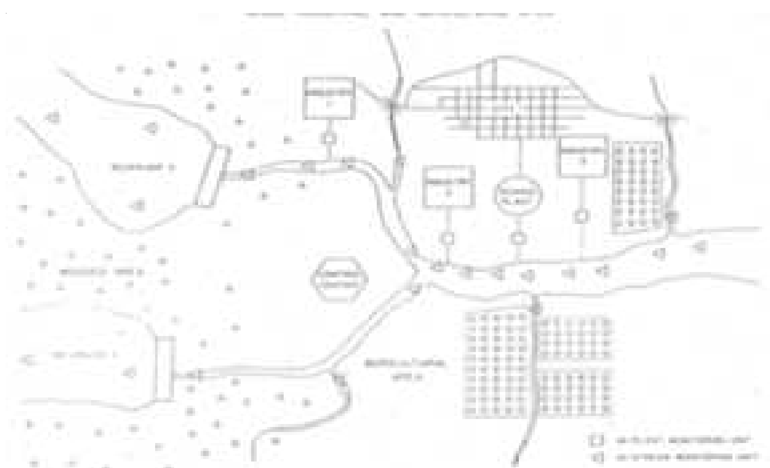

Figure-1. Schematic of location of in-plant and in-stream monitoring units to provide rapid biological information in a river management system (after 1996) maximize recycling of materials and energy, there are three categories of environmentally sound technology that can be applied into Citarum river system, including: (1) Pollution control technology, (2) Conservation and rehabilitation technology, and (3) Ecosystem design and simulation technology.

Application of pollution control technology within system management in Citarum river basin was based on schematic location of in-plant wastewater treatment facilities and monitoring devices to reduce pollution loads of point sources. Pilot plant of these treatment facilities was necessary to give some information how effective the facilities to reduce pollution and to ensure community could get benefit from learning how to protect their environment precisely. In-stream creation to protect pollution could be done through conservation of native river side biodiversity as polishing materials or with the help of bioremediation technology to rehabilitate Citarum riversides. Bioremediation is a treatment process in which indigenous or inoculated microorganisms degrade (metabolite) hazardous substances into less toxic or nontoxic substances, by creating a favorable environment for those microorganisms. Tjokrokusumo and Komarawidjaja (2005)[19] pointed out that microbes have been used since thousand of years to produce fermented food, pharmaceutical industries and treatment of wastewater. Bioremediation technology which is used consortium microbes was developed and implemented successfully in recent years for biodegradation of hazardous substances, including rehabilitation of aquaculture shrimp ponds habitat contaminated by hazardous waste.

According to Gupta, et. al. (2003)[20] that bioremediation is an eco-technology for the present century. They distinguished that bioremediation is one of the nature's prudent ways to purify the polluted environment and that degraded by the anthropogenic activities. The present day bioremediation technologies are based on the process and potentials of almost all types of life forms, for examples plants (phytoremediation), microorganisms (microbial remediation) and animals (zooremediation). However, the bioremediation process must be carefully monitored to avoid the possibility of creating a product that is more toxic than the original pollutants[21]. Created wetlands along the riverside could help managers to keep river of Citarum basin into the sub basin clean and healthy, and also to protect and keep in high biological diversity in Citarum river basin. Ecosystem design can be done through community participation in planning, implementation and evaluation. Simulation technology could help decision makers to decide what could be done to protect and to stop Citarum river system continuously degraded. Reforestation could help to protect tropical rain forest green, but without any community participation illegal logging keep on going through the ages. Therefore community participation could control and help the people to increase their cares and economic incentives to control their invaluable tropical natural resources. In addition bio-monitoring technology could help managers to monitor systematically river basin with the helps of the community (community participation) through implementation of river's macroinvertebrate community guidelines and checklist.[22] Furthermore Kluster et al. (1994)[23] considered that wetlands are havens of biodiversity and are often endangered because they can be hard to identify. Therefore, understanding their variable characteristics can lead to more successful conservation efforts, including biodiversity of macro-invertebrates along the riversides. In the upper of Citarum river basins has long neglected diversity of freshwater wetlands. Therefore assessment and rehabilitation of these freshwater wetlands are benefit for understanding and protecting of aquatic ecosystems along the riversides. Lakes are suffering from different stress factors and need to be restored using different approaches.(24) The eutrophication remains as the main water quality management problem for inland waters, both lakes and reservoirs, including multipurpose-cascaded dams (Saguling, Cirata and Juanda) in Citarum river systems. The way to curb the degradation is to stop the nutrient sources and to accelerate the restoration with help of in-lake technologies, especially lakes with a long retention time need eco-technological help to decrease the nutrient content in the free water.

In order to promote the concept of the Integrated River Basin Management, the programmatic and strategic approaches in Citarum river basin, Center of Environmental Technology (P3TL-BPP Teknologi) launched in 2003 a Cluster program, known as Environmentally Sound Management of Citarum River Basin. This program is designed to assist local governments to integrate environmental technology consideration into management and development of freshwater resources, with a view to reconciling conflicting interests and ensuring the regional development of water resources in harmony with the water-related (natural and artificial) environment throughout entire river systems.

6. Conclusions

Citarum is a strategic river basin, which are consisted three multipurpose-cascaded reservoirs needs to be observed and promoted into a better quality of river basin.

As one of the big rivers in West Java, Integrated River Basin Management (IRBM) is the best way to promote Citarum river basin into healthy river, to optimize policy interventions in space and time, to reduce potential conflicts; to bridge the potential gaps and to streamline potential overlaps between policies.

Community participation is needed to optimize community preparation for social engineering in planning, implementing, and evaluating applied science and technology in order to manage life support systems in Citarum river basin.

Bioremediation technology is promoted to be the best available eco-technology that could purify the polluted environment that degraded by the anthropogenic activities based on ecosystem approach (design of mesocosms for the purification of wastes).

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